THE UNIVERSITY OF CALGARY

ALBERTA, INFORMATION TECHNOLOGY AND THE PROPOSED NATIONAL MICROELECTRONICS FACILITY

by

D.R. Hill, G. Hope, J. Kendall

Research Report No. 83/115/4

February 1983

DEPARTMENT OF COMPUTER SCIENCE

ALBERTA, INFORMATION TECHNOLOGY AND THE PROPOSED NATIONAL MICROELECTRONICS FACILITY

by

D.R. Hill, G. Hope, J. Kendall

Research Report No. 83/115/4

D. R. Hill, Department of Computer Science, The University of Calgary
G. Hope, Department of Electrical Engineering, The University of Calgary
J. Kendall, Noval Technologies, Calgary, Alberta

SUMMARY

This paper outlines the background to current national and provincial research and development initiatives in VLSI design and fabrication. After Identifying the four enabling technologies underlying the Information Revolution, and briefly explaining the nature of VLSI. the paper goes to show the close parallels between the previous Industrial Revolution and the current Information Revolution. It Is noted that we have just reached the same critical development stage of 'inventing the machine to make machines'. The importance of VLSI and related topics to the survival of modern nations is spelled out. The current major bottlenecks in developing this important enabling technology (VLSI) are identified as lying in design manpower, design software, and mask making. In Canada the situation is particularly acute. It is noted that the current recession has, paradoxically, opened a "window" in time, during which Canada, and particularly Alberta, can take steps to participate fully in the benefits to be expected from establishing high tech industries based on the Information Revolution, and in particular on VLSI and the related software enabling technologies. Some initiatives have already been taken. What more needs to be done is spelled out within the international, national, and Albertan contexts.

ALBERTA. INFORMATION TECHNOLOGY AND THE PROPOSED NATIONAL MICROELECTRONICS FACILITY

D.R. Hill
Dept. of Computer Science
University of Calgary
G. Hope
Dept. of Electrical Engineering
University of Calgary
J. Kendall
Nova! Technologies. Calgary

February 20th. 1983

INTRODUCTION

The Science Council of Canada, concerned with advising the Federal Government of Canada on policy, has described the situation facing Canada today as "the greatest development challenge of several decades". It states that the face of industry is changing in a way not seen since the ferment of the industrial revolution. The SCC documents the urgent need for planning in their recent report: *Planning now for an information society: tomorrow is too late* (1982). Because of the importance of Information Technology (IT), both as the most rapidly growing market place in world trade, and as the dominant influence on competitiveness in all other sectors of national economic and social performance, developed countries are urgently reallocating resources. and planning massive research and development programs. All this is happening despite the most serious recession since the 1930's. It is partly early recognition of these trends that has placed Japan in Its currently dominant competitive position in world trade. Japan plans to maintain or increase that lead with its Ministry of International Trade and Industry investing at least $500M into its nationalised computer effort over the next five years; and with the individual companies involved matching the government funds many times over, bringing the total according to some observers to, perhaps $4 billion (Posa 1981).

In Britain, where considerable government money has already been spent to encourage the development and application of the new technology, on top of that spent by successful companies, the Alvey committee, in its report: *A programme for advanced information technology* (1982), recommends that the government should fund 75% of a $700M five-year research programme In what it calls the four "enabling technologies". These are:

- software engineering;
- very large scale Integration (VLSI);
- man-machine Interfaces; and
- knowledge-based systems.

These topics are central to what has been termed "Fifth Generation Computer Systems". Such systems are confidently expected to give a considerable competitive edge in world markets to their successful producers. Application of such systems will affect the competitiveness and effectiveness of all other institutions in society, and will also create new kinds of application. In Japan, there is also emphasis on desirable social objectives. Certainly, more easily used, cheaper, and more effective systems can (for example) affect the quality of administration in local, provincial and national government, or provide services that are currently uneconomic. However, there is a negative side. First there Is the potential damage to the quality and privacy of life, especially in the work-place, that has already led. In some countries, to the appointment of "data shop. stewards" to monitor and avoid damaging consequences of this kind. More serious are the socio-economic implications of failure to meet the challenge. Such a failure would lead to increasing dependence on non-renewable resources. This would occur: as competition in other markets drove us out; as new products took over; and as the cost of administering society escalated in the face of dependence on imported technology and systems.

This is why France has set a national goal of becoming the first nation to pioneer the new kind at society, and Is investing vast sums Into the relevant areas of research and development. We are at a cross-roads. It may be that we cannot afford to keep up, or that we should make a conscious choice to slide into pastoral, dependent poverty. But whatever we do, we must do it knowing where it will lead us, and we must be prepared to accept all the consequences. The message in this background paper, however, is that we can and must succeed In rising to the challenge. There is particular emphasis on the effort needed to develop a national capability in VLSI design, fabrication, and production.

WHAT IS VLSI ?

In 1946. the transistor was born as a result of basic research at Bell Laboratories in the US. Rapid development, first of the germanium transistor, then of the silicon transistor led to many important industrial products that served industry and the military, as well as consumers. The transistor radio was a sensation when it first came out, but other products were equally sensational. Amongst these were transistor-based computers that, because of the relatively low power and high reliability of transistors compared to older vacuum tubes, made computer power much more "usable", and paved the way for increased power.

Transistors work because the electrical properties of materials like germanium and silicon vary according to small amounts of deliberately added impurities ("dopants"). Different compositions, in contact, set up fields allowing large main currents to be affected by comparitively small control currents, using relatively low power. Originally, transistors were made on small chips of silicon. one at a time, with a three-dimensional structure. Soon many transistors could be fabricated on a chip by a process analogous to printing, in the sense that the patterns of impurity, connection, and the like could be laid down in what amount to two-dimensional patterns (all connections one side, with the third dimension of only microscopic extent). Fabrication progressed through integrated circuits, and large scale integration (LSI) to VLSI. Most recently, experiments have started that promise to use the full extent of the third dimension to build up successive layers of patterns to give a full three dimensional array of transistors and related components. Even with two dimensional arrays of components. the patterns are so fine (measured in millionths of a meter or less) that tens or even hundreds of thousands of transistors and related components, with their associated connections, can be placed on a chip less than the size of a thumb nail. This is VLSI. and it has made computers and similar "intelligent'"devices so small and so cheap (since mass production is possible and the mass market exists for low-cost functional intelligence) that it is cost effective to use information processing power in quite inexpensive goods -- cars, washing-machines. watches, and even toys. At the same time whole new vistas of information processing for the benefit or amusement of society have opened up. This is the information revolution. If the same progress in automobile technology had occurred, as has occurred in information processing over the last 20 years, it would now be possible to buy a Rolls-Royce for $10 and drive it round the world on five litres of gasoline.

VLSI is not just "more and cheaper"; it is a statement about possible system complexity. To quote Carver Mead, one of the leading innovators in making VLSI technology available:

> ***VLSI defines a technology capable of creating systems so complicated that coping with raw complexity overwhelms all other difficulties.***

(Mead 1981). Mead takes another analogy for progress in VLSI from Seitz (1979), who was looking at things from the designer's rather than the user's point of view. If designing chips in the mid 60's can be thought of as designing the street layout of a small town, then designing in the 80's is comparable to designing a street network covering the entire North American continent.

One further point must be made, before leaving the topic of "What is VLSI". It relates directly to the problems of managing the complexity noted above. The greatest bottleneck in exploiting the power of VLSI techniques lies in design. Increasingly the skills needed to manage the complexity of VLSI design are being recognised as those used for some time in the design of large software systems (the program suites, or recipes, needed to make computers perform the myriads of tasks they cope with). The current design toots include logic simulators, graphics packages, and (most importantly) so-called "silicon compilers". Compilers are one of many basic inventions to manage complexity of programming invented by computer scientists. Compilers allow the user to write at a higher level of abstraction or conceptualisation more appropriate to the problems being solved, instead of requiring the user to deal with incomprehensible minutiae. FORTRAN was one of the earliest compilers. Current silicon compilers, insofar as they exist at all, are more akin to assemblers. Graphics layout software is at an equally primitive stage. Expansion and innovation in these "software" areas is crucial to progress in VLSI and survival in the information revolution. This theme is developed in the introduction to the next section.

THE IMPORTANCE OF VLSI: THE INFORMATION REVOLUTION

Introduction

The information revolution is comparable in impact to the earlier industrial revolution. There are also parallels in its development, execution, and consequences. The 1957 edition of Encyclopaedia Brittanica has this to say of the Industrial Revolution, by way of introduction:

> ***When we say that a society has passed through the industrial revolution we have in mind a definite picture of its life and power. We are thinking of a society that makes great use of machinery and conducts its operations in industry and commerce on a large scale. The creation of any such society must be in some respects a gradual development. Certain features of our modern economic life can be traced back to the days when Columbus and the great sailors of his time put Europe in touch with the new world and the far East; others to the earlier history of Europe when classical Greece, and the Roman empire in turn exploited the wealth of the mediterranean basin. There was large capital invested in industry as well as in commerce before***

> ***the 18th. century, and even so modern a phenomenon as mass production was not altogether unknown before the industrial revolution. No people and no age could pass directly from a primitive and simple economy to a life so complicated as that of modern Britain or modern Germany. Some critics, surveying these earlier tendencies, doubt whether the term industrial revolution is appropriate, arguing that revolution implies sudden and catastrophic change. But a closer examination shows that the great inventions which distinguished the 18th. and 19th. centuries played so decisive a part in creating the new kind of society that the term industrial revolution, invented by a Frenchman, and made familiar by Arnold Toynbee (1852-1883), is not too violent a description of the changes they produced.***

The section goes on to note that, in engineering (which is central to the industrial revolution), probably the most important of Watt's discoveries was the use of machines for making machines. It goes on:

> ***In earlier ages, the chief obstacle to industrial development was the difficulty of land transport. In Germany and America, this difficulty was resolved by the railways. In England, on the other hand, where the sea was nowhere very far distant, an industrial revolution was possible without the railways, because canals and roads could give access to the ports. It was mechanical engineering that received the greatest stimulus from the railways. Therefore, when the world wanted railways and docks, England was ready with the plant, the experience, the capital, and the skill. Hence it was to English capital and English labour that the world turned for this task. But there was a difference between the early days of the revolution, when England sold piece goods all over the world, and the later days, when it sold railways; for the railways it sold sometimes helped to turn agricultural into industrial societies, and it was certain that when this change had taken place, England's preponderant share in the trade of the world would decline. When the 20th. century opened, England had powerful industrial rivals both in and out of Europe, many of them with far greater natural resources to exploit, and one of them, the United States, with a far greater supply of capital per worker.***

The US subsequently took over as world leader because it had learned the new technology, and was in a position to exploit it. It important to note the parallel with the currently touted 'Information Revolution'. The actors have assumed new roles but we have a similar developmental picture for information-based machines now, as they replace human brain power, and permit hitherto unthought of or previously impossible developments, as for the energy-based machines of the last revolution which replaced human muscle-power, and permitted similar innovation in activities requiring muscles.

VLSI permits, in principle, information processing of arbitrary character and complexity. The information processing made possible is the very tool needed to deal with the complexity. and make practical and affordable what is possible in principle. We are in the process of discovering the new "machine to make machines". There are some crucial differences, however. The machines of the Industrial Revolution were driven by energy, and made themselves under the direct guidance of skilled humans, who learned by experience and direct feedback how to do the jobs (a poor lathe could make a better lathe in this way). Information processing machines are driven by information (power requirements are not at issue, so no invention Is required there), and the human skills involved are at a higher level of abstraction and complexity. They are programming skills, in just the other three areas noted in the Alvey report. Indeed, the distinction between software (programs to guide information processing machines in their work), firmware (software more or less permanently written into special memory). and hardware (physical parts of information processing machines) is becoming increasingly devoid of meaning for other reasons as well. A program may be represented as a printed listing on a page. or as a printed design on a VLSI chip (Intel actually offer a chip form of a complete operating system of some complexity – CP/M on the 81501 chip). Equally, the logical characteristics of a machine – what instructions it will obey – can often be changed to create a new machine with different characteristics by altering the control store part of the hardware, which amounts to a program change.

The boundary between hardware design and software design (building the machine – usually in VLSI, and figuring out how to make it do different things) has become extremely blurred. It is hard to contemplate doing well at one without understanding the other, especially in the newer applications areas. What used to be done by so-called "random logic" (custom logic made of many standard varieties of integrated circuit and LSI chips) is now done, and will increasingly be done in the future, by custom LSI and VLSI chips. Many "systems" now fit on a single chip. Systems design involves intimate interaction between hardware and software requirements. A single chip can do what would have required a whole rack of equipment (with power to match) only two years ago. Furthermore, much of the associated software is usually incoporated into the silicon in one form or another, whilst what is left is highly dependent on the chips to an extent that has not been true before. The continuing trend towards ever more complex custom chips. and the concept of "total systems integration" that would put a complete modern telephone switching system on a relatively small area of silicon, leads to considerable reduction in costly wiring, connectors, and size. Not only is the systems phenomenon likely to increase, but the importance of custom chips, and of solving the design problem at reasonable cost, will increase. This all means that it is no longer possible to separate the design of the chips from the design of the system, or the design of the software to make the system work – especially since software serves to design the hardware in the first place. The best and cheapest systems will be produced by those able to control and match all three components in the final product, whether it be a Telidon terminal, or an intelligent toaster.

The crucial point to make is that software skills are part and parcel of the design and use of VLSI technology. In talking of fifth generation systems and their benefits, it must be noted that the four enabling technologies are actually highly interdependent. Each area draws for success on the other three, which puts this essential industrial development unequivocally at the leading edge of current research for its source of innovation and progress. At the same time, its imperative is the health of the entire nation: jobs, services, balance of trade, security, and future.

The International Context

Industry and university leaders in information technology throughout the developed world are urgently planning to meet their various national needs for highly skilled manpower in the areas crucial to survival under the information revolution by programs for retraining, and by massive new research programs. Some of these have already been noted. VLSI programs feature prominently in all this activity. Mead (1981) has stated that throughout the evolution of courses and research projects in VLSI there has been a continual difficulty in gaining access to chip fabrication facilities (even in the US). Noting the generosity of individual companies in making facilities available, he states:

> ***While these favours were crucial to getting university programs going, they obviously cannot be the basis for supplying a multititude of emerging small system firms, nor***

can they support the expanding group of participating universities. What is needed is an openly available service facility which will, for a fee, accept pattern tiles in standard format (which we have already worked out) and 'print' them on silicon wafers using a standard fabrication process.

In another paper (Mead and Lewicki. 1982) such a service facility, or "silicon foundry" is likened to the forges that serviced the earlier machine industry. The authors, certainly with the industrial revolution in mind, note that ordinary capital is consumption foregone to create productive capacity which must be wrenched free to feed the sources of creative intellect. They also describe intellectual capital as "students going to school, instead of getting a job", and it is noteworthy that the rise of education In England was based on the need to create the necessary skilled workforce for the industrial revolution. In Germany it was Bismark's response to their inability to compete with England. Intellectual capital (people imbued with knowledge and ideas) is essential as a basis for the innovation needed to employ ordinary capital to the benefit of society. (The consumer has often benefited as much as the industrialist from the resulting increase in production). In writing about the success of California's "Silicon Valley" (the "largest floating technology crap game in the world" and birthplace of: the integrated circuit; the microprocessor and microcomputer; the personal computer; the first retail computer store; and, most recently, genetic engineering). McKenna (1982) notes that 44% of all productivity gains stem from innovation and new knowledge. This compares to 16% each for economies of scale, and for new plant and equipment, and of 12% from better resource allocation.

McKenna goes on to note that the gains are most evident where computers. telecommunications, robotics, and microcomputers are being put to work. These are visible aspects of the power that now derives from VLSI. Information Technology is indeed "IT", quite literally!

So important is the provision of proper facilities for teaching and research to the production of ideas and highly skilled manpower that about 10 US universities have been given money to set up their own chip production facilities (chip foundries). Thus North Carolina has been given US$28M. and MIT US$16M. Part of this difference in funding lies in the fact that the former facility will not only have a frozen (or pilot) line, but also a development line. with which those interested In the physics and engineering of chip production can carry out investigations into better chip fabrication methods. The pilot lines serve as a training ground for chip designers, and as an experimental facility for innovation in systems design based on faculty research. However. at present, even at Stanford, students must work with chip projects put up as designs by their predecessors, the turn-around is so slow. This is hardly conducive to the highest standards of education.

The University of Oslo, in Norway, is constrained to sending chips to the US for fabrication, at present, as is the University of Edinburgh, In Scotland, which offers VLSI design to its undergraduate students. The latest news from Edinburgh is of an award worth $5M for chip research.

This view suggests that, given time, the situation may improve, with additional capacity being made available, and an international network developing. However, as might be expected In this economically vital area, the flow of information and technology is starting to be restricted. Following a series of moves by the US to counter the growing Japanese threat to their world trade in the goods and services associated with Information Technology, including trade restrictions and trade secret prosecutions, even US universities are becoming secretive about their chip production techniques and software. Economic realities are coming to the fore, and the US is no longer prepared to supply the competition (even friendly Canadian competition it seems) with free information on what is new and worthwhile in these crucial areas (e.g. Strauss 1982). Japan in the meantime has quite baldly stated its aim to dominate the world with its fifth generation systems in the comparitively near future, based on making them exceedingly powerful and very easy to use. At the same time INMOS in the UK are claiming to be able to stave off the "threat" from Japan, whilst importing licensed chip technology from the US. No country can afford to be dominated by any foreign power to the extent that is possible if the country lacks domestic capability in VLSI, beyond a few licensed (and inevitably technologically obsolescent) frozen foundries, tied to individual companies needs. Nor does it seem wise any longer to hope for purchased services abroad (even ignoring the balance of trade problem). Neither case provides the basis for being at the leading edge of technology, nor for bringing in new products to exploit the fabrication methods that are just about to become standard. Neither case provides a basis for keeping the best people in the home country. People will go where the challenges and opportunities lie. This can be a benefit if they ultimately return, bringing new skills with them, but it is a double loss if they stay away because of lack of worthwhile facilities at home.

THE CANADIAN CONTEXT

A major national effort in VLSI is essential as a component of Canada's involvement in the Information Revolution. Success in all the areas involved is vitally important to Canada's economic recovery and future health. Success will promote the growth of new industries able to compete successfully in world markets, thereby creating new jobs at all skill levels, and reducing Canada's dependence on imported information-based systems. This will affect national security as well as the balance of trade.

The industrial activity concerned is one of "high value added" goods and services. Cheap raw materials, in small quantities. are worth a great deal when sold, after processing. Such goods and services are in huge and increasing demand. Most economic activites depend on them, from manufacturing and control, through data-base and information access systems, to government activity (both military and civil). Innovation in both software and hardware, i.e. techniques and equipment, is vital to continued competitiveness for any organisation using such services. The goods and services involved are not just conventional data processing services. They comprise new applications and techniques together with components that increasingly distribute information handling power into more and more of the products on which society depends. Industrial production increasingly depends on intelligent controllers and robots. Oil discovery and production increasingly depends on new analysing tools, graphical devices, and field installed processors for well management and pipeline control. Transducers of increasing sophistication are needed for the same activity, many only possible through special VLSI fabrication. The consumer goods that sell best increasingly Incorporate built-in microelectronics to make them energy efficient, cheaper, reliable, and more convenient to use. Lucrative new markets are developing on the basis that things can be done now that were impossible or prohibitively expensive, prior to the information revolution.

Four years ago, it seemed reasonable for a country to proceed on the basis of buying in the chips needed for system design and manufacture. It is now clear that this is no longer true. However. on this basis, a number of microelectronics centres have been set up around Canada, with Federal and/or Provincial funding. Co-operation between industry and universities is being strongly encouraged, especially in the areas noted above. New courses have been set up that offer combinations of computer science and engineering.

The main emphasis of these measures has, so far, been to promote new applications for microelectronics, in keeping with the buy-In philosophy. The question posed was "what kinds of new uses, in improving productivity and creating new products, can one think of for chips". Along with this has gone a mandate to educate small and medium sized industries that might otherwise have lacked the resources to investigate such matters. One particular area of success for Canada has been that of computer communications -- for example, Telidon, the graphical system tool for accessing public data banks, comprises software built on a physical system made up of microchips.

Now that it is seen that the situation has changed, a new direction and a new urgency have become apparent. There are several reasons for this. They are all connected with the basic importance of control over the supply of chips, and the ability to have secure supplies, and to be able to design and produce them ahead of the competition. They are also connected with the fact that many systems now fit on a single chip, with all the ramifications noted above. The communications area is one of the big success areas for Canada as far as system design to date is concerned, and it is instructive to note that Northern Telecommunications have invested considerable resources into chip fabrication facilities of their own. Even so, they are currently dependent on the Japanese competition for the very highest speed devices. They also suffer from the general shortage of design skills and software for custom VLSI. What may happen, it the designer shortage is not alleviated soon, is anybody’s guess. In this we must not ignore the requirements for other companies with similar capacity, let alone the spate of existing and new companies that have no design teams at present, and cannot afford their own fabrication plants.

Part of the answer is for universities to provide the training required to produce highly skilled manpower in the relevant hardware and software areas. At present. Northern Telecom has generously and far-sightedly made some of its production facilities available, on a restricted basis, for university training. As an immediate stop-gap measure this is invaluable, and may prove to have saved the Canadian capability in the area by the example set, and conciousness raised, as much as by the facility provided. However, the total volume that can be handled within budget restrictions is likely to prove inadequate in the long run and it is planned for student projects, to educate designers. rather than as a faculty or industrial research facility. Furthermore, it cannot serve as a development line, for frontier research in fabrication technology, since it is frozen, and subject to commercial security. Since "yield" Is a critical parameter, the line cannot serve as a test-bed for better ways of making chips. Even as it stands, there is a turnaround problem and a lack of detailed Information on process parameters needed for design. At present, it takes up to a year between submitting a design, and getting it back. This is because there are currently two submission dates a year. If a design just misses one. It could be nearly six months before the next date, and a further six months to get it back. If It could be guaranteed that submitted designs would not fail during the fabrication, due to some error or misunderstanding, during the fabrication process. it would be possible to reduce the time involved by putting batches on priority, but this requires a gradual building of confidence and expertise. It also requires a possibly unattainable degree of perfection in the logistics of managing student projects and liasing with the organisation involved (the National "VLSI Implementation Centre" or VLSIIC). Northern Telecom have, in fact, promised to speed the turnaround and make some process parameters available, further indicating their goodwill and desire to help, but it is illustrative of the difficulties. Other companies (e.g. MITEL) have also offered to help with other kinds of processes. Nevertheless, one is mindful of Mead's remarks.

THE NATIONAL PROPOSAL

Against this background, a group of around 50 experts from Canadian Universities and industries, has generated a proposal to the federal government to establish a Candian silicon foundry to serve the national needs outlined above. Originally, a dual-line facility similar to that at the University of North Carolina was proposed to provide a pilot line serving the needs of education and faculty research in VLSI design, with a development line to serve the fabrication researchers. A unique facility was proposed to serve all universities, to concentrate resources, and build the kind of world-class centre that would attract staff of the highest quality (some being Canadians now working in the US). Industry collaboration and participation was seen as very important, except that the original proposal did not intend to serve industry as a foundry. This omission was seen by some as a deficiency.

The original proposal. estimated to cost around $65M over the first five years. and about $1OM a year thereafter in operating costs and perhaps $6M a year in capital renewal, has been evolving. The final form of the proposal. as submitted to the government, takes the following form. To address the design problem, a design engine is proposed. This initiative would place high-powered CAD/CAM stations at around 26 universities by the end of five years. together with testing facilities. Some universities would have more than one such station. The VLSIIC at Queen's University would be strengthened by providing a VAX 11/780 and additional staff. The centre would co-ordinate the submission of designs to companies volunteering access to their fabrication lines, and would act as a clearing house for software. Large expensive packages would be acquired by the VLSIIC to complement the basic design software supplied with with the design stations, and would be distributed over public data facilities to the participants. In addition, a further comparable sum of money would be made available to develop new software within the system. This too would be distributed and maintained by Queen's VLSIIC. The total cost Is budgetted at $27M over 5 years. including the provision of funds to extend the industrial fabrication services.

To cover the original "development line" proposal, the current submission proposes a distributed approach, to capitalise on existing expertise. However, one centre would be the major centre, and up to three "minor" centres would also be supported – no more. The major centre would have the capability of taking a chip through all stages of creation. It Is proposed that this aspect of the national initiative would be partly funded by industry, and a joint management board would be set up with a program committee and director under it to coordinate research plans at different centres to avoid unnecessary duplication of research effort. Links would also be made with the design engine. Equipment for both initiatives would be owned by the organisation and could be recalled and transferred as needed. The fabrication initiative would consume a budget of around $60M over live years.

No production facility, or service to small industry is envisaged.

The prospects for obtaining funding for the design engine seem good. The future of the other part of the proposal is less clear, but both are clearly necessary, and even together, they address but part of the total problem.

THE ALBERTA CONTEXT

Alberta and the NMF

Alberta has pursued a policy of diversification and expansion, thus planning for the future, and avoiding imprudent dependence on resource based industries and agriculture. There are difficulties in pusrsuing this policy. Apart from the need to husband scarce financial reserves wisely and cope with a serious recession, new industries require skills, and may run into problems of competition, access to markets, and potential for growth.

No matter where the National Microelectronics Facility (NMF) for chip fabrication is located, there will undoubtedly be a serious problem recruiting the skilled persons needed to run the line successfully. However, some successful industrial lines have been set up in Canada, and start-up skills and technology can still be obtained (though for how long ...). Part of the reason for creating such a facility is to be able to grow our own expertise to solve just this kind of problem.

As far as the problems of competition, access to markets, and potential for growth are concerned, proposals to create facilities are:

(a) intended to allow Canadian efforts in the new information-based industries to be more competitive;
(b) addressing an area where the potential for growth is more of a certainty than a potential;
(c) aimed at an industry for which access to markets, especially transportation, largely ceases to be a problem, whether one is discussing microchips. or software. Even complete systems are normally air-freighted since, with modern technology, they are small and valuable.

Point (c) is or especial relevance to Alberta.

On the subject of husbanding scarce resources wisely, one can only point out that, in the current situation, making the investment necessary to support any Initiative in VLSI can only be regarded as a unique, incredibly valuable opportunity to get In on the ground floor of a whole new range of modern, high-technology industries. As Silicon Valley in California, and to a lesser extent the Silicon Valley North (the Ottawa valley), have shown, high technology investment has a snowball effect. The NMF will undoubtedly prove to be an entrepreneurial nucleation centre of the first magnitude, creating new industries, wealth, and jobs in the area, as well as training the manpower needed to fuel the expansion. The NMF promises to be a very potent seed.

Many of the above points are general in nature and could be raised by responsible people in any part of Canada where such an activity could be contemplated at all. Indeed, It Is to be fervently hoped that good sense will prevail, and the NMF will be set up, much as planned, possibly even extended as suggested below. However, there are two important problems. First, it is not clear that the Federal government will be able to afford the full cost. despite optimistic predictions, at least not immediately. Yet speed is vital, especially given the rapidly increasing difficulty of acquiring the information and skills needed for start-up, not to mention the need to establish a market position for Canadian products in this area. Thus there is a budgetting problem. Secondly, there is the question, peculiar to Alberta. as to why it would be good for the country, and for Alberta in particular, for the NMF to be located in Alberta.

On the budgetting side, we see Alberta provided with a unique opportunity to make a key investment that will be good for Canada, good for Alberta, and should repay itself many times over. Moreover, it is an investment that should help to guarantee that this important project goes ahead In the face of federal fiscal constraint. With the right kind of initiative from Alberta, in terms of sharing the cost and providing an appropriate future-growth environment (such as a research park, or university reserve), the federal government may find itself presented with a sufficiently reduced commitment that it is able to proceed with dispatch. Nevertheless, whether the facility is located in Alberta or not, the provincial government should seriously consider a generous contribution if only out of the enlightened sell-interested point of view that what is good for Canada is almost certainly good for Alberta.

From a National point of view, there is some merit in locating the facility in Alberta. First, it avoids a total concentration of skills in the East. and shows a willingness to develop the potential of Western Canada. Secondly. it places the NMF on the traditional North-South line of communication with the many West-coast facilities in the states -- likely of help in recruiting, attracting visitors, obtaining raw materials for chip production, and possibly mitigating the worst effects or any restrictions on knowledge exchange that may arise. Alberta has a more attractive winter climate than Vancouver, and a more attractive summer climate than Ontario and Quebec. It offers the kind of challenging leisure pursuits that attract highly motivated and technically skilled people, and has great potential for future growth.

An Alberta Proposal

Regardless of how the National question is settled, it makes excellent sense to consider major Albertan initiatives in VLSI. The rewards are great, the time exceedingly opportune, and a provincial facility, quite apart from fuelling real diversification and growth in the province, could address areas untouched even by the full national proposals. A three-tier integrated facility could be built, in conjunction with industry brought into Alberta and would immediately create overwhelming drive for further new industry in high growth areas. Suitable contacts already exist. However, if the province delays. the recession will end, and the opportunity will be lost for good.

The details of a proposal for Alberta to enter the Information Technology stakes form the subject of separate documents. Here it is only intended to state a few broad ideas, independent of the final outcome of the full provincial steering committee deliberations. However, a silicon foundry would be an important component of any major proposal.

Two possible scenarios are somewhat similar to the two proposals, original and current, that are being considered by the national steering committee. It is the third alternative, however, that is probably the most attractive. It involves the immediate creation of a profitable high tech venture, entirely funded by industry, according to business plans already drawn up and supported by potential partners with the required expertise.

The Alberta government and the Alberta Research Council have favoured joint ventures as a means of promoting research arid devlopment to encourage the expansion or creation of industrial activity in the province. In the case of the proposed facility, which is very expensive, a number of immediate problems may be alleviated if the facility, rather than being a cut-down version of the original NMF proposal, were an expanded version: a three tier proposal that went in phases over several years (though not too long), with the aim of providing a development line (for fabrication research), a pilot, line (for design education and systems research), and a production line. The production line would provide a custom VLSI service to all comers, and would also develop VLSI macro-circuit techniques at the leading edge of the technology, based on in-house expertise acquired in the set-up. The pilot line would aim to provide for the research needs of industries (especially small, new, innovative industries) as well as universities, and would be compatible with the production facility. Designs produced as a result of research, which had commercial potential. could be moved to the production facility without costly redesign involved in moving to a new process. Possibly some kind of sliding scale fee would be applied for industrial users, if the demand were heavy, but it would be subsidised in keeping with Alberta's joint R & D venture philosophy. The production line would be expected to become profitable within a reasonable period and would very likely be the first component to come on stream. As noted, this third tier would be industry financed. However, it could share a building with the provincial R & D facilities, perhaps owning it and renting space to the province, or perhaps renting space from the province. The benefits would be considerable. A centre, unique in Canada, would have been created. Not only would its scale, quality, and comprehensiveness be very attractive to building its strength because high quality staff would wish to work there, but it would form an entrepreneurial nucleation centre of the first magnitude for the province. Furthermore, it would be in a very strong position to compete for federal funds of various sorts, to the extent that they became available, without being dependent on them. There are several other advantages. No one participant in this world class facility would carry too much of the cost. Even the cost of the production facility would be shared, and the government would avoid the necessity of taking an equity position in a commercial venture. The company would also be spared the application of government constraints in dealing. with their problems of running a business. Nevertheless, the value of having excellent R & D facilities heavily subsidised by government immediately adjacent would be incalculable. The synergistic effect would be part of the attraction to user and service companies.

The attractions of the production facility to participating companies would be varied. First it is addressing a market that Is estimated to reach $95B dollars by 1995. With only a tiny percentage of the world market, it is realistic to project total sales in excess of $500M by 1990. The facility could act as a secure second source for a series of companies who would value access to new design skills provided by cross-licensing agreements. Even Northern Telecom may be interested. Certainly a number of companies inside and outside Canada have shown interest. For this the quality, price and delivery would have to be right, but that is a *sine qua non* anyway. Secondly, companies may be glad to have someone else manufacture their tail-end runs, which could be a valuable source of cash flow and profit in the start-up phase. Most importantly though Is the provision of state-of-the-art custom

VLSI design and fabrication facilities, that begin to meet the needs expressed in the earlier part of this document, and allow Canada to take advantage of what is a unique window in time (created, paradoxically, by the recession) to catch up with and exploit the current information technology revolution, and set up world class semiconductor systems and software facilities in Alberta.

ACKNOWLEDGEMENTS

The authors would like to thank the many people who, by suggestion. constructive criticism, and freely given knowledge have helped to bring this draft to its present form. They are too numerous to mention. However, one person does deserve special mention, and that is Graham Birtwistle, who helped gestate a first draft of this document, and who has provided unflagging encouragement to keep up the original momentum that he helped to start. It should be noted that Graham has organised a VLSI design course to run at Calgary in June, having already run one In October 1982 that gave an Introduction and overview. The principal author would also like to acknowledge, with gratitude, the support of a Killam Resident Fellowship from the U of Calgary which made the completion of this work possible.

REFERENCES

ALVEY. J. (1982) *A program for advanced information technology*. HMSO: London, UK

MEAD. C.A. (1981) VLSF and technological Innovations. *VLSI 81: Very Large Scale Integration* (Gray, J.P. Ed.): Academic Press: London

MEAD. C.A. & LEWICKI. G. (1982) Silicon compilers and foundries will usher in user-designed VLSI. *Electronics* **55** (16), pp 107-111, August

McKENNA. R.M. (1982) Encouraging a risk culture. *Electronics* **55** (16), p 24 , June

POSA. J.G. (1981) How Japan's chip makers line up to compete. *Electronics* **54** (1), pp 113-132, June.

SCIENCE COUNCIL OF CANADA. (1982) *Planning now for an information society. tomorrow is too late.* SCC Report Number **33**, 77 pp . .

SEITZ. C. (1979) Self-timed VLSI systems. *Proc. Caltech Conf. on VLSI,* January

STRAUSS. S. (1983) Data freeze: Canadians catch the fall-out from information war. *The Globe and Mail.* Toronto. Monday, January 3rd.